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TITLE: SYSTEM FOR DETECTING AND RELEASING A PERSON LOCKED IN THE TRUNK OF A VEHICLE

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SYSTEM FOR DETECTING AND RELEASING A PERSON LOCKED IN THE TRUNK OF A VEHICLE

BACKGROUND OF THE INVENTION

1. Technical Field of the Invention

The present invention concerns safety systems for operating automobiles and, more particularly, to such a system that detects the presence of a person in a closed trunk and releases the person under safe operational conditions.

2. Description of the Related Art

There have been well publicized reports of young children inadvertently locking themselves in the trunk of a vehicle, such as an automobile. Tragically, children can die under such circumstances, typically as a result of heat prostration while trapped in the sealed trunk.

It has been suggested that a trapped person could actuate an inside release mechanism to open the trunk. However, it is not certain that a young child would understand how to operate such a mechanism and it is therefore possible that the child would not be able to free himself by this means. There is therefore a need for a system that detects the presence of a person, particularly a small child, within a trunk and signals the need to open the trunk. It would also be advantageous for such a system to automatically trigger a trunk to open and release the trapped person when it is safe to do so, for example when the vehicle is stopped.

There is therefore a great need for an automatic trunk safety system. The apparatus and system of the invention has been developed to meet this need with simple, relatively low cost and reliable components that are easily integrated with the electronic control systems of existing vehicles. The above-mentioned features and other features of the invention will become apparent from a review of the following drawings, specification and claims.

SUMMARY OF THE INVENTION

One embodiment of the apparatus and system of the invention includes a sensor that detects CO_2 that is exhaled by a person trapped in the closed trunk of a vehicle. A microprocessor compares the level of CO_2 detected in the trunk to a baseline level of CO_2 that was measured the last time the trunk was opened. If excessive CO_2 is detected, the microprocessor determines the operational state of the vehicle and takes programmed steps to provide an alarm and to automatically open the trunk if the vehicle is not moving.

Other embodiments of the invention can use infrared sensors or electrostatic (i.e., capacitive) sensors to detect a person in the trunk. Systems with such sensors would also operate automatically to provide an alarm and to open the trunk under safe operational conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1A and 1B are a block diagram of the CO_2 sensor, microcontroller and related apparatus that provide the trunk safety features of the invention.

Figures 2A and 2B are a flow chart of program steps used by the microcontroller to implement the trunk safety system of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the drawings, elements are not necessarily drawn to scale, and the same reference numbers through several views designate the same or similar elements. Figures 1A and 1B illustrate a block diagram of components of the system of the invention in association with known electronic components of a modern vehicle. As shown in FIG. 1A, a CO_2 sensor 1 includes the elements shown within the dashed lines. This sensor has a CO_2 sensing component 3 that detects the level of CO_2 in the trunk of a vehicle such as an automobile.

CO_2 sensors are commercially available. A preferred sensor is sold by Figaro USA, Inc. of Glenview, Illinois with the model designation TGS4160. This solid electrolyte sensor generates an output voltage on a line 5 that corresponds to the level of detected CO_2. The sensor includes a heater

element 7 that must be energized in initial operation to heat the sensor to a specific operational temperature. The sensor therefore requires some initial time, for example, about 2 minutes, to stabilize before it can make a reliable CO_2 reading. A thermistor 8 senses the temperature of the sensor and applies a corresponding voltage to a microcontroller 15 that, as an example, may be a model 68HC705P6A device which is commercially available from Motorola. The output voltage of the sensor is applied to the plus input of a difference operational amplifier 9 that also receives at its minus input 11 a reference voltage from the microcontroller 15. The operational amplifier 9 generates an output voltage on line 12 that corresponds to the difference between the voltage at its plus and minus inputs.

It has been found that the response time of an internal thermistor of the preferred CO_2 sensor is generally too slow for use in a commercial CO_2 vehicle detection system. An external thermistor 8 with a relatively rapid response time must therefore be used. This thermistor must detect the temperature of the CO_2 sensing element so that the microcontroller can compensate for changes in sensor temperature and thereby accurately detect the level of CO_2.

In initial operation, the reference voltage at 11 from the microcontroller 15 is adjusted to produce a particular voltage, for example 4 Volts, from the operational amplifier 9 at output 12. This reference voltage at 11 represents the baseline CO_2 concentration and is held constant through the monitoring cycle. The signal at the operational amplifier output 12 is amplified within the microcontroller, temperature compensated and monitored for changes.

If a person is thereafter trapped in the trunk, the level of CO_2 will gradually rise above the background level. As the concentration of CO_2 in the trunk rises, the voltage on the line 5 decreases and the amplifier 9 generates a voltage that corresponds to the difference between the decreased voltage on the line 5 and the background reference voltage on the line 11. The output of the amplifier at 12 therefore corresponds to the relative increase in the concentration of CO_2 from the baseline. The “delta” voltage corresponding to the change in the concentration of CO_2 is applied to the microcontroller and, if

a specified magnitude of this voltage, for example 1 volt, is maintained for a specified time, for example 30 seconds, the microcontroller registers an alarm. The alarm magnitude of CO_2 may be set to correspond to the respiration of the lowest weight person within the parameters of the system.

The microcontroller 15 receives vehicle status signals and transmits control signals over a serial bus 14, through a serial data interface 16 that may operate with the J1850 or Controller Area Network protocols as an example. Other protocols could also be used.

With reference to FIG. 1A as an example, the microcontroller may be hardwired to a trunk latch switch 18, a trunk release solenoid 19, left and right rear seat switches that indicate the latched or unlatched condition of these seats at 20 and 21, an override switch for temporarily disarming the CO_2 sensor at 22 and a status lamp at 23 that indicates the operational condition of the CO_2 detection system, for example by blinking.

The serial bus communicates with the instrument cluster electronic control unit 26 which receives a signal from the manual trunk release switch 24 and controls a CO_2 panel alarm lamp and/or audio alarm 25. An engine control module 29 monitors the operational state of the ignition key switch 27 and interacts in a known manner with an automatic braking system 34 that connects with a high-speed motion control bus 28 and receives signals from wheel speed sensors 30 that indicate whether the vehicle is moving. With reference to FIGS. 1A and 2A, a body control computer 48 controls a relay 45 that operates the vehicle horn and lights and responds to a remote keyless entry system 42 in a known manner. A radio frequency data module 53 can be actuated to send radio alarm signals to a remote security station via a satellite communication system 51 in a known manner. A heating, ventilation and air-conditioning module 56 operates a vent fan 54 in a known manner. The fan could be disposed to vent the trunk, for example, in response to a CO_2 alarm. A known plug-in service diagnostic tool 70, other known vehicle control modules 68 and the headlights 64 are connected and operated on the serial data bus 14 in a known manner. All of the apparatus on the serial bus is monitored and controlled through the

microcontroller 15 that also controls the operation of the CO_2 detection system. If necessary, the microcontroller could be implemented with flash memory to facilitate program changes in the field.

As an alternative to the use of a serial data bus to send and receive vehicle control signals, the microcontroller 15 could be directly connected to send and receive these signals using a dedicated wire for each signal. In such a system, an ignition on signal from the ignition key switch 27 would connect directly to the microcontroller 15, rather than indirectly through the engine control ECU 29 and a serial data bus 14. Likewise, wheel speed sensors 30, trunk release switch 24, audio alarm or lamp 25, headlights 64, horn relay 45, trunk vent fan 54, and any other such vehicle control apparatus would connect directly to the microcontroller, rather than through associated modules and a serial data bus.

Figures 2A and 2B illustrate a flow chart of microprocessor program steps that implement the system of a preferred embodiment of the invention. As shown at the top of FIG. 2A, for the purpose of this discussion, the CO_2 detection system is initially assumed to be in a sleep state at 17 wherein the system waits for an activation condition. The system is awakened or activated at least in response to opening the trunk of the vehicle or unlatching either of the back seats. With reference to FIG. 1A, when the trunk is opened or at least one back seat is unlatched, the switches 18, 20, 21 indicate the activation condition. The activation signal is passed to the microcontroller 15, for example over a hardwired connection.

With reference to FIG. 2A, the microcontroller 15 therefore detects the activation condition at 31 and wakes up and sets a delay time to process CO_2 information. With reference to FIG. 1A, when the microcontroller 15 wakes up, it begins to monitor the CO_2 sensor 3. The heater 7 is then turned on, the system then waits for the sensor to heat up, for example for about 2 minutes, and the microcontroller 15 then waits for the trunk to close or the back seats to latch at 37.

The microcontroller checks the condition of the trunk and seats at 37 by interrogating the switches 18, 20, and 21. If the switches do not close

within a predefined delay time, for example several minutes, the microcontroller is put to sleep to await activation by closing the trunk or latching the seats. When activated, the baseline CO_2 is acquired and stored, a timer is set and, if necessary, the sensor is warmed up. The concentration of CO_2 in the trunk is measured at 39 during a predefined time-out interval of, for example 20 minutes. If an increase in the level of CO_2 is detected in an amount that would be exhaled by a human being, the "trunk occupied" condition is triggered at 43. The system is put to sleep if the timer times out at 44.

Experimentation and investigation have indicated that healthy human beings in a calm, relaxed or sleeping state, that is their basal metabolic rate, exhale CO_2 in amounts proportional to their body surface area and age. When active, frightened or otherwise agitated healthy human beings exhale CO_2 in amounts greater than their basal metabolic rate. Thus, for example, an individual 180 pounds, 35 years old, 5'10" and male would exhale about 200 milliliters of CO_2 per minute in his basal metabolic rate. An individual 20 pounds, 18 months old and 3'0" would exhale about 85 milliliters of CO_2 per minute in his/her basal metabolic rate. An infant of 7 pounds is estimated to exhale about 22 milliliters of CO_2 per minute. The microcontroller 15 is programmed to measure the increase in CO_2 within the trunk over time in relation to the measured base line CO_2 and make a determination that the increasing CO_2 results from the respiration of a human being.

As an initial approximation, if the largest trunk contains about 566 liters of air, it has been determined that the CO_2 sensor will detect respiration at about 353 PPM (parts per million) per minute for an adult, 150 PPM per minute for a toddler and about 38 PPM per minute for an infant. This increase in measured CO_2 over a reasonable time, for example up to several minutes, distinguishes the respiration of a human being from expected changes in ambient CO_2. The detection of a gradual increase in CO_2 also serves to distinguish an abrupt increase in CO_2 that might result if a person intentionally injects CO_2 into the trunk in an effort to confuse the CO_2 detection system. As an example, it has been found that human respiration can be distinguished by

measuring a predetermined change in the output voltage of the operational amplifier 9 of FIG. 1, for example a change of about 1 volt, for an interval of about 30 seconds.

With reference to FIG. 2A, if an occupant is not detected in the trunk within a predefined set time, the timer times out at 44 and the microcontroller 15 terminates its detection of CO_2 and sets itself in a low power sleep mode defined at step 17. The microcontroller will remain asleep until the trunk is opened again or at least one rear seat is unlatched.

As shown at FIG. 2B, if the level of CO_2 detected in the trunk indicates an occupant is present, the microcontroller 15 at step 46 turns on the CO_2 lamp 25 of FIG. 1A and/or provides an audio alarm on the front console of the vehicle, sets a timer and checks the condition of the latches on the back seats of the vehicle at step 47.

If a back seat is unlatched, the trunk is ventilated through the airspace provided by the unlatched seat and the level of alarm is therefore reduced. As shown at step 47, if a back seat is unlatched, the movement of the vehicle is checked at 49 and the front console alarms are continued for a time-out period. If the vehicle stops during this period, the trunk is automatically opened by the trunk release solenoid 19 (FIG. 1A) at step 50 to allow the person to escape safely. The alarms are then turned off and program control is returned to step 33 (FIG. 2A). If the vehicle continues moving, the timer times out, and at step 52 the horn is activated at 45, 48 and the headlights are flashed at 64 (FIGS. 1A and 1B). This continues for as long as the vehicle continues moving. If the vehicle stops, the trunk is automatically opened at step 58 to allow the person to escape, the alarms are turned off at step 60 and program control is returned to step 33. When the trunk is closed, the CO_2 concentration is checked and the system is put to sleep if there is no alarm condition or, if the trunk remains open beyond a time-out interval, the system is put to sleep until the trunk is closed.

If an occupant is detected in the trunk and it is found at step 47 that the back seats are latched, the status of the ignition system 27, 29 (FIG. 1A) is then checked at step 57 (FIG. 2B). If the ignition is turned off, the

microcontroller 15 sends an "open trunk" signal to the trunk release solenoid 19 (FIG. 1A) at step 62 (FIG. 2B) and therefore causes the trunk to open. The trunk is opened in this situation because the vehicle is stopped and it is therefore safe to open the trunk and allow the occupant to escape. After opening the trunk, the alarms are turned off and program control is returned to step 33.

If the sensed condition of the ignition at step 57 is "on", the microcontroller 15 at step 61 (FIG. 2A) determines whether the vehicle is moving by analyzing wheel speed signals from sensors 30 of FIG. 1A. If the vehicle is not moving, the trunk is automatically opened at step 63, the alarms are turned off and program control is returned to step 33. The trunk may be opened in these circumstances, because, even though the ignition is on, the vehicle is not moving and it is therefore safe for the occupant to leave the trunk.

If the vehicle is moving at step 61, the microcontroller 15 times out a predetermined interval at step 65 and continuously checks at step 66 to determine if the vehicle remains moving during this interval. If the vehicle stops during this interval, the trunk is opened at step 67 to allow the occupant to escape, the alarms are turned off, and control is returned to step 33 as previously described. If the vehicle is still moving at the end of the time-out interval of step 65, a higher level of alarm is generated at step 69 by triggering a radio alert at 51, 53 (FIG. 1B) to call a remote security station. Also, at step 71, the horn is actuated and the lights are flashed as previously described. When these higher level alarms are set, the movement status of the vehicle is again checked at step 73 and, if the vehicle stops, the alarms are turned off and the trunk is opened at step 75 and program control is returned to step 33 as previously described. If the vehicle continues to move, alarms continue to operate until the vehicle stops.

This CO_2 detection and response system may operate with an exit switch that is located in the trunk and lighted for a predefined time after the trunk is closed. If this switch is activated by a person trapped in the trunk, the microcontroller 15 will wake up and open the trunk or provide appropriate

alarms depending upon the operational state of the vehicle. An override switch may be activated when the trunk is open to prevent the trunk from automatically opening after it is closed. This override condition could be automatically released when the trunk is manually opened again. It has been suggested that the override switch could have the same effect as the exit switch if the override switch is pressed when the trunk is closed.

Variations and modifications of the embodiments disclosed herein may be made without departing from the scope and spirit of the invention. For example, the CO_2 detector may be replaced or augmented by infrared and electrostatic capacitive sensors. At present it is believed that use of a CO_2 sensor is preferred, because infrared and electrostatic sensors might not be able to detect a person if, for example, the trunk is partially filled with cargo. The system could also be modified to open an air vent to the trunk or partially open the trunk to allow ventilation in the event of an alarm condition. Additional conditions would also be defined to wake up the microcontroller to process peripheral equipment or interrupts for vehicle systems other than the CO_2 system. The system of the invention could also be used to monitor CO_2 in the cabin of a vehicle, in order to detect the presence of an occupant, especially a young child on a hot day, and then take safety precautions such as opening vents or windows and generating audio, visual or radio alarms. Indeed, the system of the invention could detect CO_2 respiration in any enclosure and could automatically take any required safety precautions or activate any required alarms. The aforementioned description of embodiments of the invention is therefore intended to be illustrative rather than limiting and it should therefore be understood that the following claims and their equivalents set forth the scope of the invention.